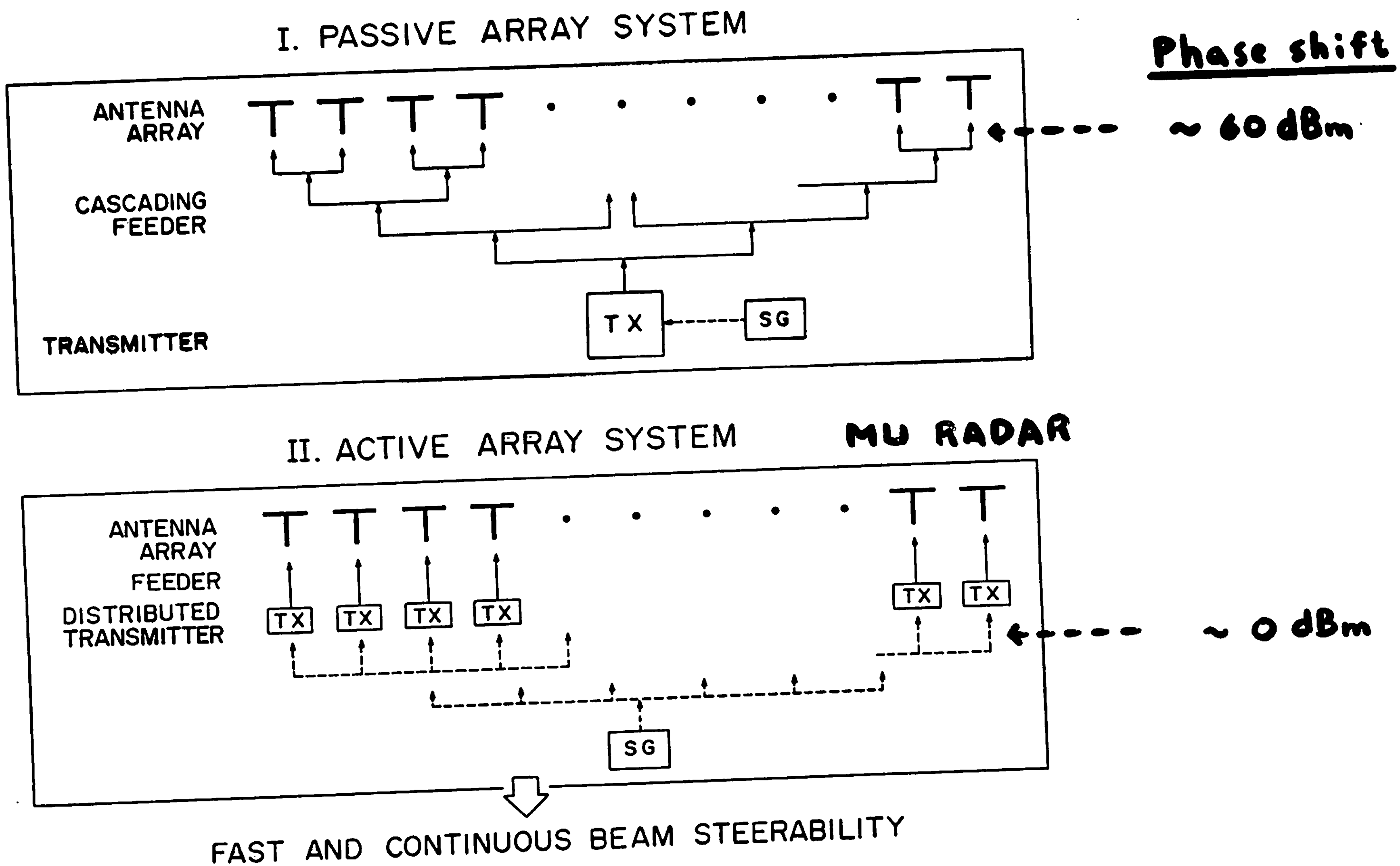
MU Radar

Shoichiro Fukao
Kyoto University


I. PASSIVE ARRAY SYSTEM
ANTENNA ARRAY
CASCADING FEEDER
TRANSMITTER
TX
SG
Phase shift
~ 60 dBm
II. ACTIVE ARRAY SYSTEM
MU RADAR
ANTENNA ARRAY
FEEDER
DISTRIBUTED TRANSMITTER
TX
SG
~ 0 dBm
FAST AND CONTINUOUS BEAM STEERABILITY

Basic parameters of the MU radar

Radar system:	Monostatic pulse radar; active phased array system
Operational frequency:	46.5 MHz
Antenna:	Circular array of 475 crossed Yagi antennas
Aperture:	8330 m^2 (103 m in diameter)
Beam width:	3.6° (half power for full array)
Steerability:	Steering is completed in each IPP
Beam directions:	1657; 0-30° off-zenith angle
Transmitter:	475 solid-state amplifiers (TR-modules; each with output power of 2.4 kW peak and 120 W average)
Peak power:	1 MW (max)
Average power:	50 kW (duty ratio 5%) (max)
Bandwidth:	1.65 MHz (max) (pulse width: 1-512 μs variable)
IPP:	400 μs-65 ms (variable)
Receiver:	
Dynamic range:	70 dB
A/D converter:	12 bits × 8 channels
Pulse compression:	Binary phase-coding up to 32 elements (Barker and complementary codes presently in use)

RADAR SENSITIVITY

$N_e = 10^{12}\ m^{-3}$

$R = 300$ km

τ (Pulse width) = 500 μs

L (Loss factor) = 0.75

$B \propto \tau^{-1}$ or Δf

Table 3. Comparison of the MU radar sensitivity with other existing IS radars.

IS Facility	Freq. (MHz)	P_t (MW) (peak / avg.)	A (m^2)	T_{sys} (K)	B (kHz)	S/N
Jicamarca	49.9	6.0 / 0.4	71900	10000	2.4	1400
Arecibo	430	2.0 / 0.1	45500	150	23.4	2000
Millstone Hill A	440	5.0 / 0.25	2334	150	24.0	260
Millstone Hill B	440	5.0 / 0.25	930	150	24.0	100
Millstone Hill C	1295	2.5 / 0.125	190	150	70.4	4
Sondrestrom	1290	5.0 / 0.12	400	100	70.4	22
EISCAT A	933	1.5 / 0.1875	560	115	50.8	11
EISCAT B	933	1.5 / 0.1875	560	40	50.8	30
EISCAT C	224	2.0 / 0.25	3360	220	12.2	200
ALTAIR A	415	20.0 / 0.112	1640	785	22.6	150
ALTAIR B	155.5	10.0 / 0.112	1640	992	8.4	160
MU	46.5	1.0 / 0.05	8330	10000	2.4	27

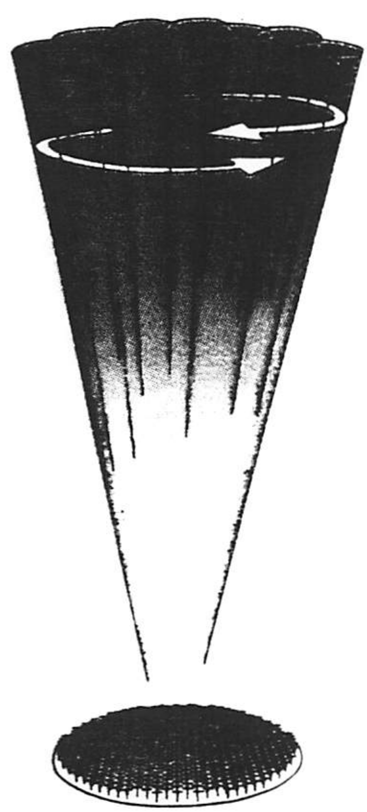
Note Not all of the radars listed above normally operate, nor in some cases are able to operate, with the listed parameters. Nevertheless, the above comparison should give an adequate idea of the relative potential sensitivities of these radars for long-pulse power measurements.

Capability I

Pulse-to-pulse beam steerability
min IPP=$400\ \mu$**s or max PRF=** $2500 KH_Z$

⇓

Many different directions
observable simultaneously



Capability I (continued)

- Simultaneous radial wind measurements capable in different directions

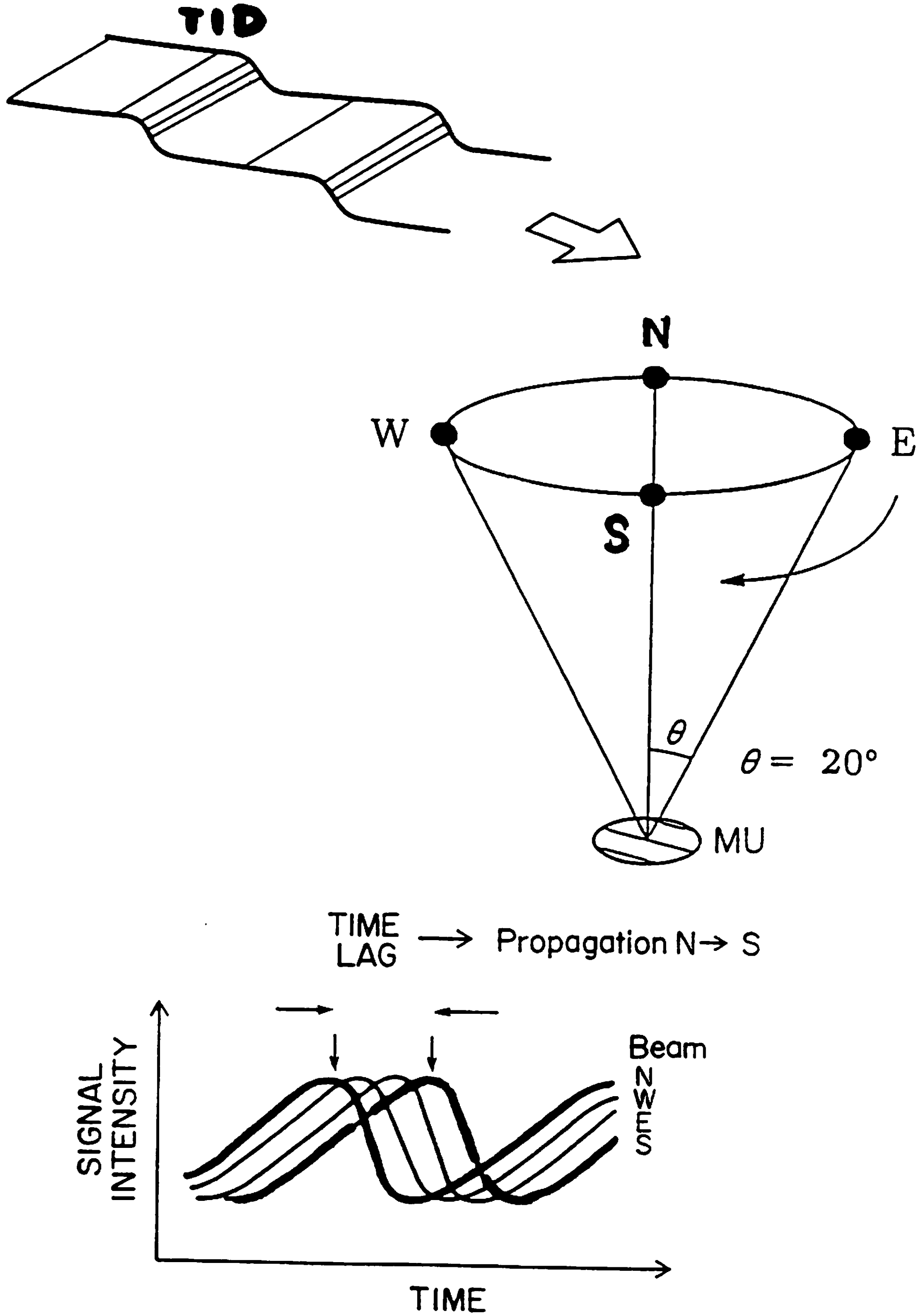
⟹ Accurate determination of wind vectors

- Ionospheric measurements capable in different directions

⟹ Spatial variability of the ionosphere

- Radio Acoustic Sounding System (RASS)

.
.
.

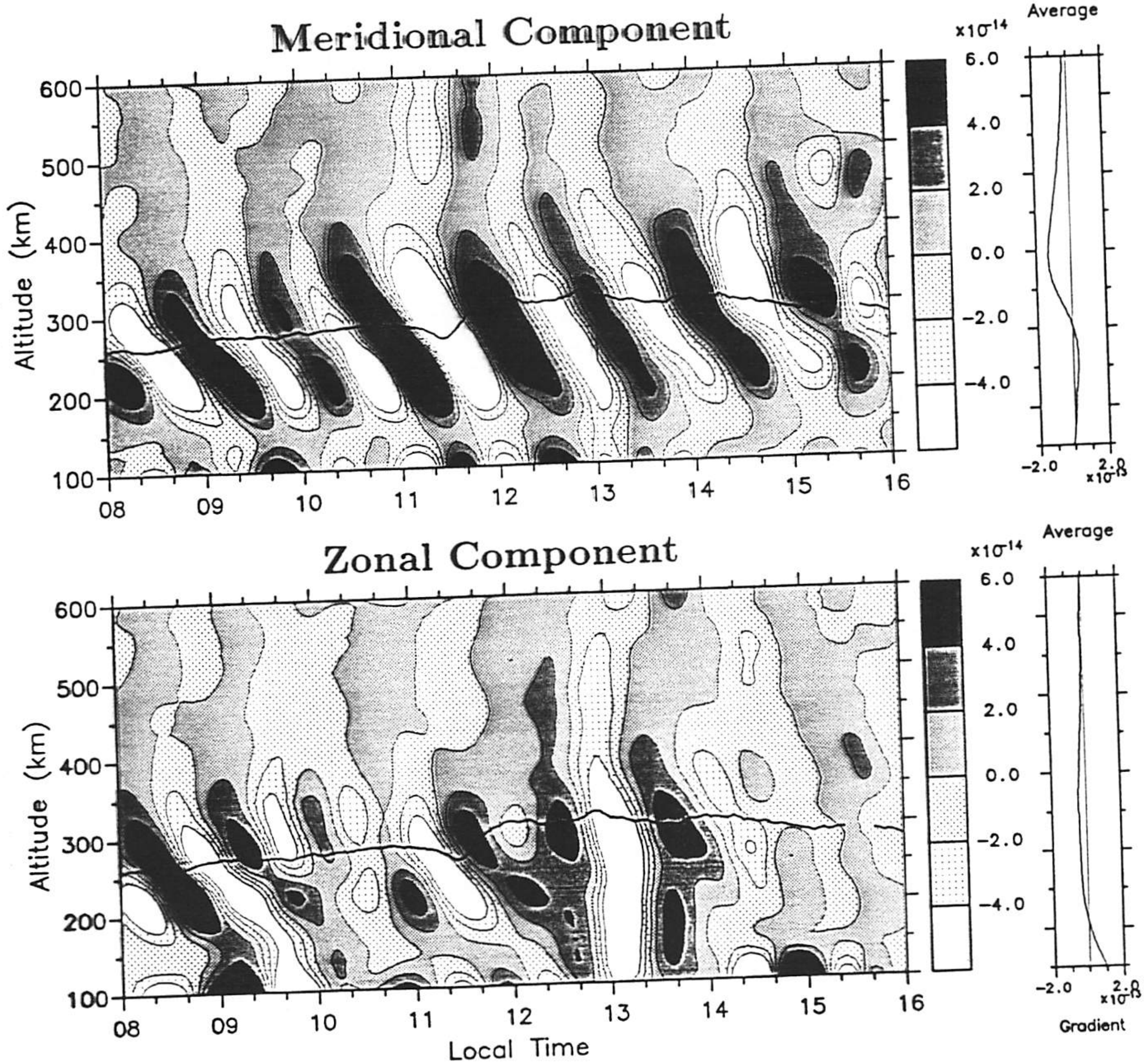


TID
N
W
E
S
θ
θ = 20°
MU
TIME LAG → Propagation N→ S
SIGNAL INTENSITY
Beam
N
W
E
S
TIME

GRADIENT OF SIGNAL INTENSITY

15-NOV-1990 08:01 – 15-NOV-1990 15:58

pass band : 50.4–100.8(min.)



Capability II

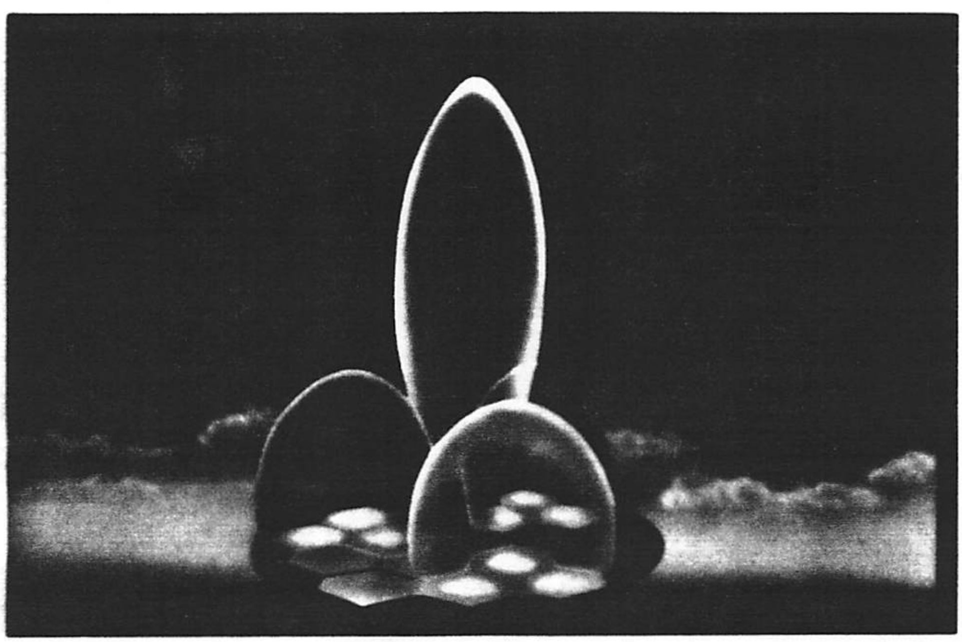
Dividable into several subarrays

⇓

Multi-beam available

- Up to 4 beams
- For any combination of subarrays

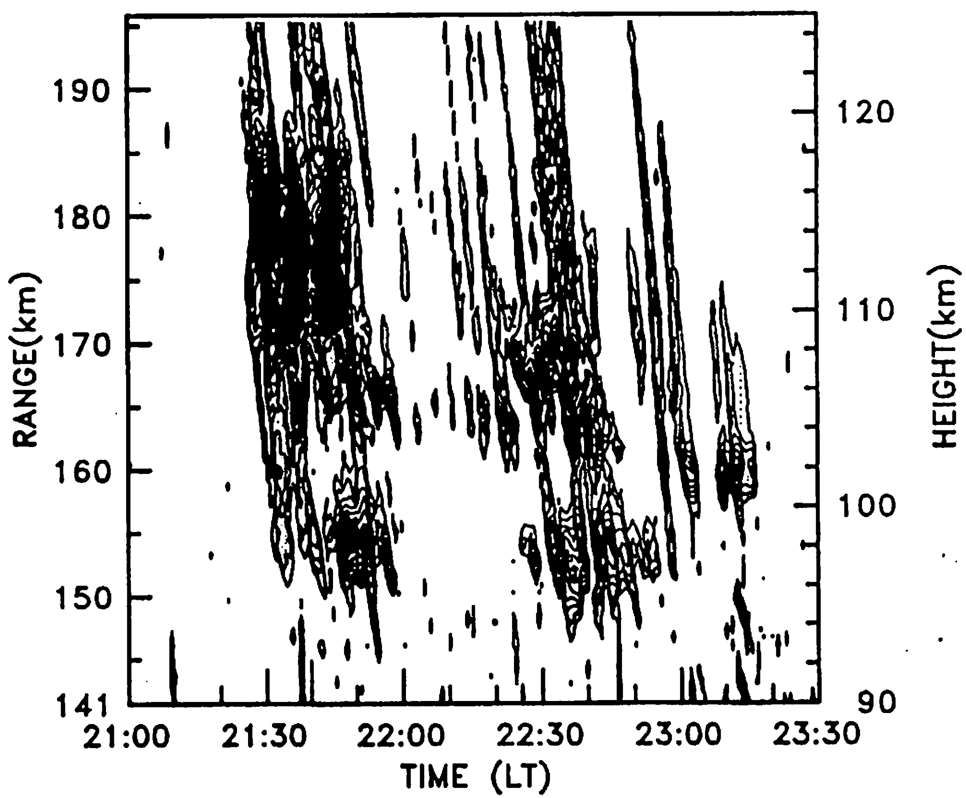
⇓



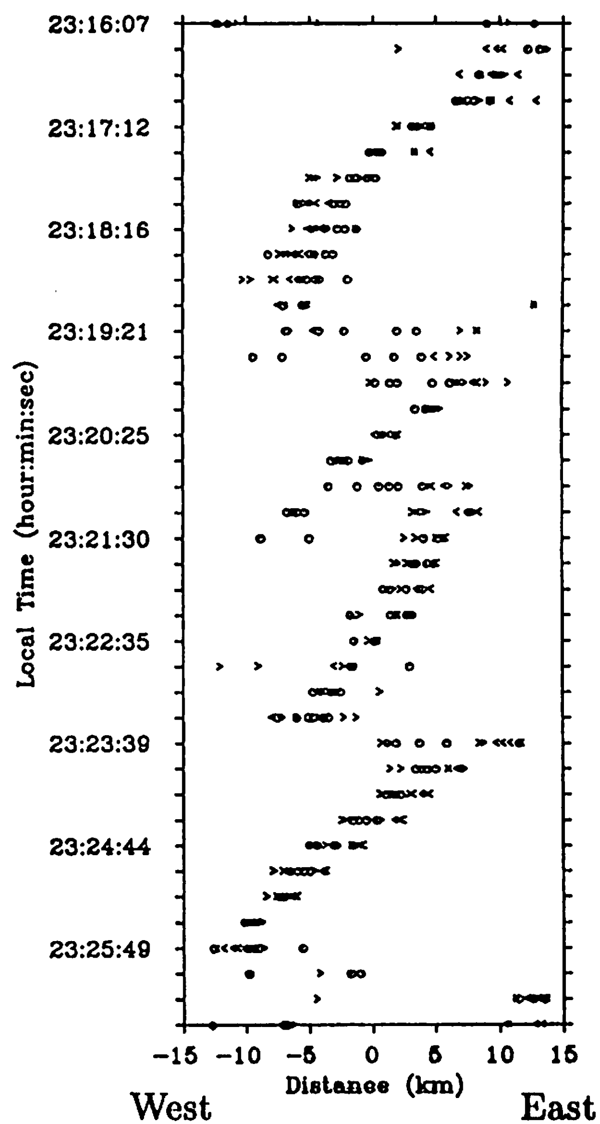
Radar interferometry

"QUASI-PERIODIC" ECHOES

Due north perpendicular to B



Transverse horizontal positions

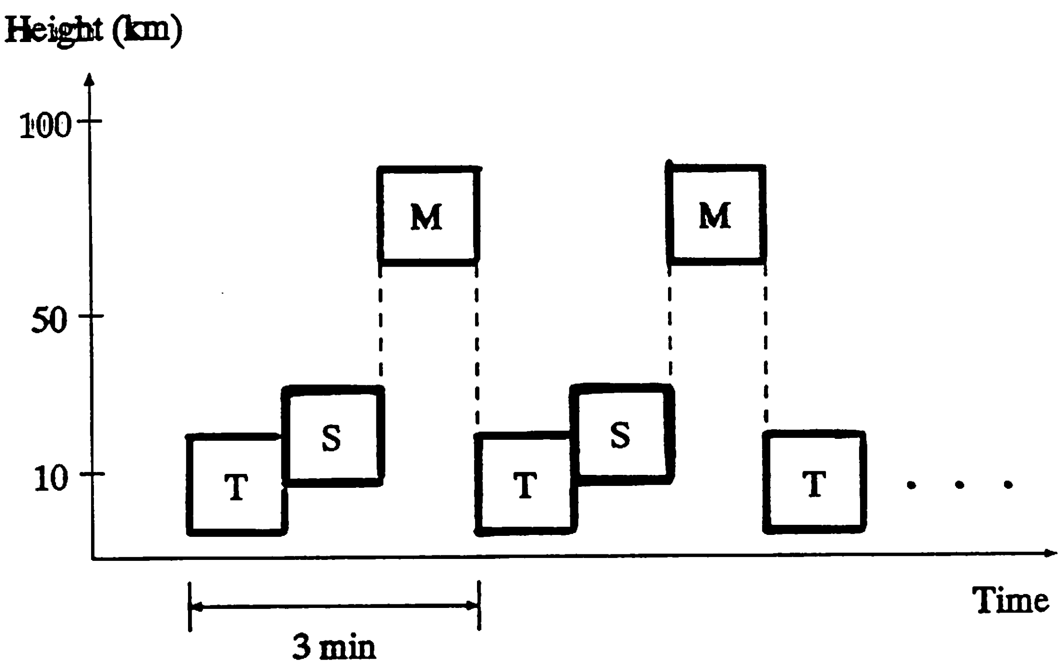


Capability III

Rapid switching of observational programs/parameters

⇓

Different height ranges observable almost simultaneously



	Δh	IPP	Pulse code
T:Troposphere	150m	400μs	Single
S:Stratosphere	150m	400μs	16bit Comple.
M:Mesosphere	400m	730μs	8bit Comple.

******* THE MU RADAR *******

DERIVABLE QUANTITIES IN THE CLEAR AIR

- **WIND VECTOR** ; $u,\ v,\ w$

  $\Delta T \sim min, \quad \Delta h \sim 10^2 m$

  - VERTICAL WAVENUMBER SPECTRUM
  - FREQUENCY SPECTRUM
  - DOMINANT INTERNAL GRAVITY WAVE

- **VERTICAL MOMENTUM FLUX**
  - and VORTICITY AND DIVERGENCE?

- **TURBULENCE**
  - STRUCTURE AND LAYER TILT
  - VERTICAL EDDY DIFFUSIVITY

- **TROPOSPHERIC METEOROLOGICAL PHENOMENA**
  - FRONTAL PASSAGE
  - COLD AIR DOME, TYPHOON, ...

- **TEMPERATURE**
  - using RASS TECHNIQUE

******* THE MU RADAR *******

DERIVABLE QUANTITIES IN THE PRECIPITATING AIR

- The 50-MHz MU radar can detect precipitation echoes simultaneously with the echoes from the ambient air.

- Therefore, the rain drop-size distribution N(D) can be derived without any assumption of the mean vertical air velocity,

- in addition to all quantities derivable in the clear air.

******* THE MU RADAR *******

DERIVABLE QUANTITIES IN THE THERMOSPHERE/IONOSPHERE

- **IONOSPHERE** ; *Ne, Vd, Te and Ti*
  - DIURNAL VARIATION
  - SEASONAL VARIATION
- **THERMOSPHERE** ; *Vns and* $Tn\infty$
  - SEASONAL VARIATION
- **IONOSPHERIC DISTURBANCES**
- **ATMOSPHERIC WAVES**
- **3-m IRREGULARITIES IN THE F AND E REGIONS**

JAPAN PROGRAM
FOR
U.S. POST DOC

- NSF / JSPS Awards for
  one-year visit to Japan
  (Univ. in)

- Fully supported

- MU radar related research at RASC/
  Kyoto Univ. welcomed

Please contact !!

NSF Japan Program staff or m

for further information